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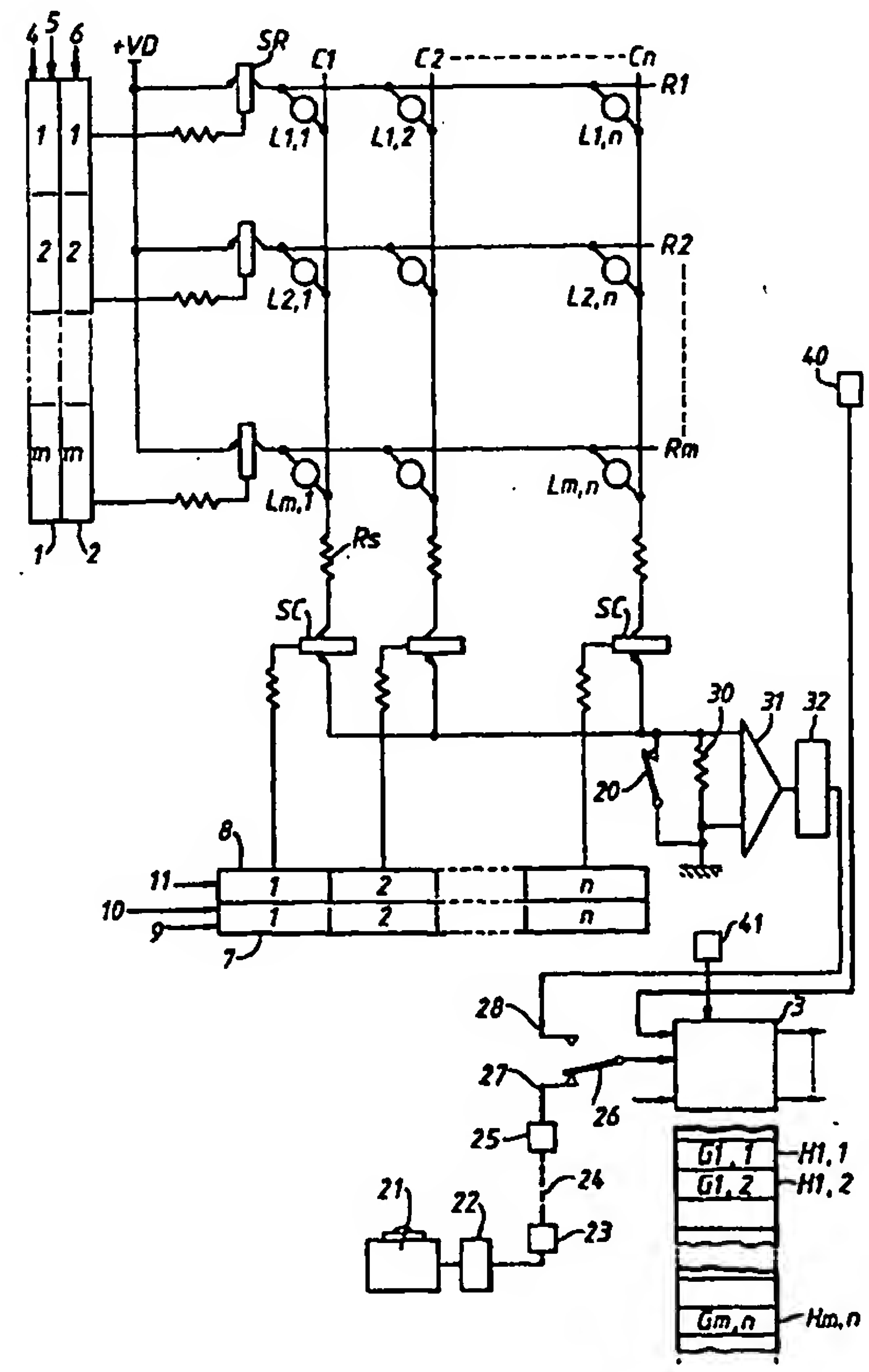
(57) Abstract

A display matrix having LED lamps L is arranged so that the effect of brightness and color variations between the lamps, due to the lamps having different characteristics and temperatures from each other, is reduced. A process for setting up the display using an electronic camera (21) is described. The system is arranged so that the brilliance of the lamps is automatically maximised when the sun is shining on the face of the display.



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DISPLAY SYSTEM WITH BRIGHTNESS CORRECTION

BACKGROUND OF THE INVENTION

The present invention is concerned with enhancing the appearance of display matrixes in which each pixel comprises an LED lamp. It is also applicable to matrix displays using other types of lamp, such as incandescent filament lamps, and to display panels using lamps that are not necessarily arranged in a uniform manner.

A problem in designing LED lamp matrixes is that of achieving uniformity so that all the lamps give the same light output. The light output of a new LED at a given temperature is dependent on its light efficiency, measured as light intensity at unit current, and on the operating current. Also LEDs are subject to intensity degradation, i.e. fading, with prolonged use.

For most types of LED lamp the light efficiency, often expressed in the form of luminous intensity at 20 mA, can vary from sample to sample by about 5:1. For some types, the diodes are sorted from the production line to have a lower ratio of maximum to minimum light efficiency form sample to sample, for example 2:1.

In an LED matrix with multiplexed drive, current is limited in each LED, usually by means of a resistor that is in series with the LED when it is turned on, and the matrix is preferably driven from a 5 volt supply to avoid reverse breakdown of the LEDs and to keep the power consumption low. The current, I, in a selected LED in such a case is given by:

$$I = (5 - V_L) \div R_S$$

where V_L is the forward voltage drop of the LED and R_S is the value of the current limiting resistor. V_L can vary from 1.8 to 3 volts for some types of LED, and using such types the current, I, can vary from a maximum value of $3.2/R_S$ to a minimum value of $2/R_S$, i.e. in the ratio 3.2:2 . Thus if the initial light efficiency varies by 2:1, the light output can vary by 3.2:1. Added to this are variations in intensity degradation with time, and variations due to the differences in the voltage drops across the switches routing the currents to the LEDs.

Yet another factor affecting uniformity of an LED display matrix is that the junctions of the LEDs are not all at the same temperature. Those that are on, or have recently been on, are hotter than those that have been off. The difference between the hottest and the coolest junction temperature at any one time can be as much as 50 degrees centigrade. Since the light intensity of an LED can drop by 1 % per degree centigrade, this represents a further 2:1 mismatch in intensity. The effect is dynamic. The time constants of junction temperature change can be of the order of a second for the LED itself and tens of seconds for its heat sink, which is typically its printed circuit board.

Not only are there intensity mismatch effects, but there are also color mismatch effects. LED lamps can be initially mismatched in color, when received from the manufacturer, by as much as 11 nanometers in wavelength for some green LEDs. Furthermore, LEDs are subject to dynamic color mismatch, due to dynamic temperature mismatch of the lamps. Further still, LEDs are subject to color degradation, i.e. change of color with prolonged use, which can itself cause color mismatch, since the lamps are not used equally and, in any case, are not guaranteed to have the same rate of degradation.

SUMMARY OF THE INVENTION

In the arts of television and photography an intensity mismatch ratio of 1.05:1 is established as discernible, as is a color mismatch, for green, of 0.7 nanometers. The above discussed variations in LED performance are much wider, and are thus a hindrance to achieving with LED matrixes images of a high quality. It is an object of the present invention to provide an LED display matrix in which all the lamps give the same light output, matched in color as well as in intensity, and free from the dynamic effects, and to achieve these results with a low-cost matrix drive system. It is a further object of the present invention to arrange that the display is as bright as possible in broad daylight, while keeping within the maximum current and junction temperature ratings specified by the LED manufacturer.

The present invention achieves the aforementioned objectives by providing a control system by which the performance the lamps is measured, in some embodiments with the aid of a video or digital camera, and the ambient light falling

appearance of the display. In one embodiment the differences in light output between the lamps is minimised for all ambient light intensities up to a certain limit. Above this limit uniformity of lamp lighting is partially or wholly sacrificed to achieve maximum brilliance. The control system alters the brightness of each lamp individually by altering the proportion of time for which a register bit that selects the lamp is set. In one embodiment the brightness of the lamp is also dependent on a constant current circuit that delivers to the lamp a current that depends on the ambient temperature of the lamp.

In a further embodiment, for each pixel of a display, the color of a first lamp of the pixel is adjusted by turning on a second, different colored, lamp of the pixel, so as to match all the pixels in color. In yet another embodiment of the invention an electrical characteristic, such as the current, is measured continuously during display, for each lamp. This measurement is used to reduce mismatch between the lamps, in brightness and color, due to unequal temperatures of the lamps.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates setting up a lamp matrix display according to the the invention;
FIG. 2 illustrates the control of the display;
FIGS. 3a, 3b illustrate two kinds of lamp that can be used in the display;
FIG. 4 illustrates an alternative control for the display.
FIG. 5 illustrates in cross section an arrangement for sensing light from the lamps.
FIG. 6 illustrates another arrangement for sensing light from the lamps.
FIG. 7 illustrates a further arrangement for sensing light from the lamps.
FIG. 8 is a view of the arrangement of FIG.7 taken across section XX.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIGS. 1 and 2 illustrate an embodiment of the invention comprising a display matrix having m rows and n columns of lamps L. Lamp L comprises a light emitting diode the anode of which is connected to the row conductor R and the cathode to the column conductor C as illustrated in FIG. 3a. When a lamp L is energised it constitutes a luminous area. When lamp L is not energised it constitutes a dark area, by contrast with the luminous areas. The lamps are mounted on one or more panels not shown.

Information is displayed on the matrix by driving each row R, in turn, positively for a brief period T_R; the drive being repeated continuously in the order 1,2,3,...m, 1,2,3,.....m, 1, 2,.. and so on. Within the period T_R that a row is driven, selected lamps L within the row are illuminated by turning on transistors SC of their associated column conductors C. T_R may be of the order of 0.1 milliseconds.

A row is selected by setting its associated bit within parallel latch register 2 low and the remaining bits high causing the transistor switch for just that row to turn on. The data in register 2 is set up by microprocessor 3, which first loads the data into serial-in parallel-out shift register 1, and then strobes it into register 2 by applying a pulse to terminal 6. Data is loaded into register 1 by means of its serial data input 4 and its clock input 5. Registers 1 and 2 are each of m bits.

Selection of the columns also is under control of microprocessor 3. Microprocessor 3 loads serial-in parallel-out shift register 7 by means of data and clock inputs 9 and 10 respectively, and then transfers the data in register 7 to parallel latch register 8 by a pulse to strobe terminal 11. A column is selected, by its transistor switch SC, when its associated bit in register 8 is high. Current passes from the selected row through lamp L to the column switch SC and then to ground via closed switch 20. Register 8 has a ground terminal, not shown, which can be connected either to ground or to the emitters of transistors SC.

During selection period T_R of a row, microprocessor 3 sets up register 8 256 consecutive times, at the rate of once every T_A seconds, where $T_A=T_R/256$. This is to enable the brightness of each lamp, as perceived by the viewer, to be set to any one of 256 different values. The brightness to which a lamp is set to is dependent on a value of a parameter G particular to the lamp which is held in a location, H, in microprocessor memory that is, also, particular to the lamp. The value of G ranges from 1 to 255. For G = 255 the lamp is turned on with maximum brightness as it is turned on for the whole of the row selection period TR. For G =1 the lamp is turned on with minimum brightness.

In general, microprocessor 3 controls the brightness of lamp $L_{x,y}$ (i.e. the lamp at row x, column y) by setting bit y of register 8 high for $G_{x,y}$ consecutive periods T_A

during the selection of row x, where $G_{x,y}$ is the value of G stored in memory location $H_{x,y}$ for lamp $L_{x,y}$. Thus the proportion of time for which a bit in register 8 is set to select a lamp determines the brightness of the lamp. Microprocessor 3 receives data to be displayed on the matrix via one of its input ports. The data can come from a data link, a personal computer or from any other source.

Apart from operating in the display mode described, the display of FIGS. 1 and 2 can also be set to one of two initialising modes, depending on the availability of a light sensing unit 21. If such a unit is used switch 26 is set to position 27 and switch 20 is kept closed. Light sensing unit 21 can be a video camera pointed at the matrix of lamps L. Lamps L are all turned on at maximum brightness by setting G equal to 255 for every lamp. The lamps are turned on briefly, for less than 0.1 seconds, so as not to heat them. The output of video camera 21 is transmitted to microprocessor 3 and the image of the matrix is stored in memory. Transmission from camera 21 to microprocessor 3 is with the aid of an analogue-to-digital converter 22 and infrared transmitter 23, which transmits the digitised image data over optical path 24 to infrared receiver 25. Receiver 25 is attached to the cabinet housing the matrix. Transmitter 23 is attached to the camera or its tripod and aimed at the receiver. Camera 21 may be a digital still camera, in which case converter 22 is not needed. The stored image is analysed by microprocessor 3 to obtain brightness readings for all the lamps. The brightness readings are scanned by microprocessor 3 to determine which lamp L is the least bright, and the brightness of this weakest lamp is taken as a reference brightness. Following this, the brightness reading of each lamp is used by microprocessor 3 to set the G value for the lamp in its memory location H. The value of G being given by:

$$G = (255 \times \text{Reference Brightness}) \div \text{Brightness reading for the lamp}$$

The value of G is rounded to the nearest whole number. This completes the initialisation process. The camera can be dispensed with and the system is ready for display, with all lamps appearing to have substantially equal brightness. The weaker lamps get more power than the stronger ones to achieve the uniformity. The proportion of time that a lamp is turned on, and therefore the power applied to it, is proportional to the value of G for the lamp.

Initialisation can be can be carried out periodically, for example once every year, to compensate for unequal fading of the LED lamps with use. To simplify the software

that analyses the information received from the camera, the procedure for measurement can be altered so that each lamp in turn is turned on by itself and a picture taken by the camera while the lamp is on. The pictures can be taken at the rate of several per second. The number of lamps turned on for each picture can be more than one if desired. The procedure can be altered so that the camera is pointed at only a quarter of the matrix at a time, if the resolution of the camera is low. To eliminate the effect of ambient light, which may appear as reflections off the face of the sign, on the reading for a pixel, the system can be arranged to measure the light from the pixel both when it is on and when it is off, and to take the difference as being the true reading.

As an alternative procedure, camera 21 can be connected to a laptop computer the display screen of which shows the image viewed by the camera. The laptop computer is used to analyze the light intensities of the pixels and to compute the G values, which are later sent to the display for storage in memory compartments H. Transfer of the G values can be by recording them on a medium which is subsequently read into memory H.

As another alternative, an ordinary film or Polaroid camera can be used for setting up the G values. Two photographs are taken, one with the lamps all on and the other with them off. The photos are analysed, using a scanner to read them and a personal computer to work out the differences between the photographs and to compute the G values. The G value are subsequently transferred to memory H, which is preferably of the non-volatile type

The display matrix may be a colour one, where a pixel area can be set to any one of a wide range of different colours. In this case three LEDs are used for the pixel; one red, one green, and one blue. The three LEDs may be mounted behind a common diffuser. Alternatively they can be mounted close together so that when viewed at a distance the eye perceives the pixel area to be of only one apparent color, which is the sum of the three emitted colors. For pixel one of row one of the colour matrix the three differently coloured LEDs are wired as $L_{1,1}$; $L_{1,2}$; $L_{1,3}$ and for pixel two of row one they are wired as $L_{1,4}$; $L_{1,5}$; $L_{1,6}$ and so on along the row. Rows 2 onwards are wired using the same principle. During energisation of a pixel, the durations for which its three associated bits in register 8 are set are made

dependent not only on the G values, but also on other values held in memory that define the relative intensities of the three pixel lamps needed to achieve the required hue for the pixel. Thus, a required light output U_{rgb} for a pixel is achieved by driving its three LED lamps as follows:

Red lamp: $N_r = G_r \cdot P_r$

Green lamp: $N_g = G_g \cdot P_g$

Blue lamp: $N_b = G_b \cdot P_b$

where N_r, N_g, N_b are the number of intervals T_A during T_R that the red, green, blue lamps are driven for, respectively; G_r, G_g, G_b are the G values for the red, green, blue lamps, respectively; and P_r, P_g, P_b are values, each not greater than one, held in memory, defining the amount of red, green, blue light, respectively, that the color pixel is required to generate. For example, if the color pixel is required to generate blue-green light at maximum intensity, then $P_r = 0$, $P_g = 1$ and $P_b = 1$. It has been assumed so far that the red lamps are identical in color, and similarly with the green lamps and the blue lamps. The case where for one or more of the three colors the lamps are mismatched both in color and intensity will be discussed later.

The multiplication products $G_r.P_r$ etc. can optionally be achieved by providing a read-only memory of 65,536 words of one byte each, which has stored in each word the most significant eight bits of the product of the two bytes that together form the address of the word. The memory is presented with a 16-bit address consisting of the two bytes that are to be multiplied together, such as G_r and P_r and the read-out of the memory is the required product.

During initialisation It is possible, instead of using a camera as light sensor 21, to use a photo cell. In this case each lamp in turn is turned on with the photocell receiving light from it and the digital reading for the lamp light is recorded in microprocessor memory.

An alternative to initialising using a camera or a photocell is to measure the LED current, instead of its light output. In this case switch 20 is opened and switch 26 is set to terminal 28. Each lamp L is turned on in turn by selecting just its row and column conductors and a measurement of its current is made with the aid of resistor 30, which may be 1 ohm, and amplifier 31 and analogue-to-digital converter 32. The measurement is stored in a location of memory of

microprocessor 3 associated with the lamp. After all the lamp currents have been measured and recorded the measurements are scanned to determine which lamp has the weakest current. This weakest current is established as a reference current. The microprocessor is then used to set up a value for G given by:

$$G = (255 \times \text{Reference Current}) \div \text{Current measured for the lamp.}$$

After setting up the G values switch 20 is returned to the closed position, ready for display. The system will now compensate for variations in lamp brightness caused by inequalities of the lamp voltage drops and by variations in the transistor voltage drops.

The system in FIG. 2 is arranged to dim all the lamps when the ambient light weakens. A light sensor 40 with digital output is arranged to measure the ambient light and transmit its digital value to microprocessor 3. For low values of sensed ambient light, for example at dusk or at night, microprocessor 3 introduces a time delay between driving each row and the next. This reduces the light output of the display but does not alter the relative brightnesses of the lamps, which are still controlled by the G values.

The lamps L in FIGS. 1 and 2 can each comprise several LEDs connected together in series, to give more power. Alternatively, they can be of another type than LED. For example they can be tungsten filament lamps. A simple way of selecting the tungsten lamps is to provide each with an ordinary diode D in series, as illustrated in FIG. 3b. The light output of tungsten lamps can fade with time. This is due to the formation of dark coatings on the inside surfaces of the bulbs after prolonged use, those bulbs that are turned on often becoming darker than those that are not.

FIG. 4 illustrates another embodiment of the invention. The operation of this with regard to matching the lamps by optical means is the same as that of FIG. 2. The lamps here are driven with constant current the magnitude of which is arranged to vary in accordance with the output of a temperature sensor 41. Temperature sensor 41 is mounted on the display so that it is subjected to the same ambient temperature as the LEDs. The ambient temperature of an LED is taken to mean the temperature of the LED when no electrical power is applied either to it or its neighbours. The output of temperature sensor 41, which can be digital, is fed to microprocessor 3.

Microprocessor 3 is arranged to set up a 4-bit register 52 in accordance with the measured temperature t_a. When t_a is below a certain threshold temperature, t_c, equal, for example, to 50 degrees centigrade, the value in register 52 is set to fifteen. As the measured temperature t_a rises above t_c, lower values than fifteen are set up in register 52 by microprocessor 3. The output of register 52 is fed to a digital-to-analogue converter 53, the output of which, in turn, is fed to a unity-gain power amplifier 54. Thus the voltage applied to the bases of transistors CC is controlled by microprocessor 3. When a column C is selected, its transistor CC together with the associated resistor 50 act as a constant current device delivering to the selected LED a constant current that is independent of the voltage drop across the LED and that is dependent on the output voltage of amplifier 54, and, so, adjusted in accordance with the sensed temperature t_a. The value of resistor 50 is chosen so that when register 52 is set to fifteen the LED current is the maximum allowed by the LED manufacturer. For sensed temperatures above t_c the value in register 52 is set to the highest value for which the LED junction temperature will not go above a certain limit t_u, chosen not exceed the LED manufacturer's maximum junction temperature rating, which is typically 110 degrees centigrade. In this way the daytime brightness of the sign is automatically maximised while keeping within the LED manufacturer's maximum current and temperature ratings. As an example, microprocessor 3 can be arranged, when t_a exceeds t_c, to set the contents Y of register 52 according to the formula:

$$Y = 15 - a.(t_a - t_c)$$

where a is a constant of the order of 0.25.

Using camera 21, the arrangement in FIG. 4 can be set to give equal light outputs for all the lamps in the same way as was described in relation to FIG. 2. The arrangement compensates for the effect of variations of the constant currents from column to column, as well as the variations due to differing LED initial light efficiencies and variations that have occurred due to degradation.

In the arrangement in FIG. 2, if the lamps are of the LED type, microprocessor 3 can be arranged to reduce the proportion of time for which lamps L are turned on when the temperature sensed by sensor 41 is high, so as to prevent the LED junction temperatures from exceeding the manufacturer's rating. The reduction of the

proportion of time can be achieved by introducing a delay between driving one row and driving the next, as was described before in relation to dimming the display at night.

In a further embodiment of the invention, applicable to both FIG. 2 and FIG. 4, microprocessor 3 is arranged to use light sensor 40 not only to dim the brilliance of the sign as darkness approaches, but also to increase the overall brilliance of the sign under conditions of extreme ambient light, such as strong sunlight falling directly onto the face of the sign. Microprocessor 3 is arranged, on detecting strong ambient light, to cease to drive the lamps so that they have equal light outputs and, instead, to drive each lamp either for the full period T_R, to achieve maximum brightness for the lamp, or for the maximum period for which the lamp brightness will not exceed that of any other lamp by a certain factor, for example 2. In this case uniformity is wholly or partially sacrificed in the interest of maximum overall brightness, but only when the ambient light is extreme. When the ambient light falls microprocessor 3 reverts to setting the lamps equal in brightness.

The lamps in the arrangements of FIG. 2 and FIG.4 need not necessarily be the lamps of a display matrix. They can be the lamps of an instrument display panel. The lamps of the instrument panel may be of different groups each group having its lamps set to a brightness particular to the group. In this case during initialisation with camera 21 the lamps of the first group, the group required to have the highest brightness, are turned on at maximum brightness, to determine which lamp within the group is the weakest, and its brightness is taken as the reference brightness, as explained before. The G values of the lamps within the group are then set to give equal brightness of the lamps. Following this, for each remaining group each lamp within the group is assigned a G value given by:

$$G = [\ (255 \times \text{Reference Brightness}) \div \text{Brightness reading of the lamp}] \times RB_n$$

where RB_n is the required ratio of the brightness of the lamps of group n relative to the reference brightness. The values of the constants RB_1, RB_2, RB_3, etc. are permanently held in memory and initially chosen by the designer of the instrument panel. The designer also specifies for each lamp which group it is in, this information being permanently recorded in memory.

The instrument panel may include preprinted light diffusers each provided with a

rear lamp which, when lit, causes the printing on the diffuser to become visible. In this case all the back-lit diffusers can be treated as one group, and initialisation will result in all the diffusers having an equal brightness, which is predetermined relative to the brightnesses of the other groups. The lamps of the panel need not all be of the same type and they need not all have the same value of current limiting resistor.

In yet another embodiment, using either of the arrangements in FIGS. 2 and 4, the invention is arranged to provide a display that has pixels of matched color using LED lamps that are themselves not matched in color. The embodiment will be described with reference to an RGB color display matrix, on the basis that the green LED lamps are mismatched in color. In this embodiment, when for a color pixel only the color green, with an intensity factor P_g, is required, then instead of turning on just the green LED lamp for:

$$N_g = G_g.P_g \quad \text{periods } T_A$$

during row selection time T_R, as described before, the control turns on the red lamp also, for:

$$N_{rgs} = G_r.P_g.Z_{rg} \quad \text{periods } T_A$$

where Z_{rg} is a color correction factor for the green LED lamp, held in non-volatile memory specifying the proportion of red light that must be added to the light emitted by the green LED lamp to achieve green of the same dominant wavelength (i.e. the same perceived color) for all the pixels. Adding red light in this way matches all the pixels so that they have the same apparent color when they are turned on to green, when their lamps are at the same temperature.

During priming, a color camera, 21, is pointed at the display and the values of G_r for the pixels are established, using the red channel of the camera for light measurement. Similarly, the values of G_g are established using the green channel, and those of G_b using the blue channel. Having equalized the lamps in intensity, the values of Z_{rg} for the pixels are then established as follows. The green LED lamps are turned on, one at a time, several at a time, or all simultaneously, at the same light intensity, W_{ge}. For each pixel the intensity, W_{rg}, of red light emanating from the green LED lamp is measured, using the red channel of the camera, and recorded. The values of W_{rg} are then scanned to find $W_{rg}(max)$, corresponding to the pixel for which the green LED lamp generates the most red light. The color of

this lamp is taken to be a reference color. For each pixel, the value of Z_{rg} is evaluated by:

$$Z_{rg} = [W_{rg}(max) - W_{rg}] / W_{ge}$$

and stored in non-volatile memory. By this expression all pixels turned on to green will emit light having the same proportion, $W_{rg}(max)/W_{ge}$, of red to green light as the reference color.

Blue can be used instead of red to match the green lamps in color. Alternatively, blue can be used to correct the green lamps that have more than a chosen amount of red; and red to correct the remainder of the green lamps. In matching the pixels, a lamp of standard intensity and color, measured by the same means as the lamps of the matrix, can be used as the reference to which the lamps of the matrix are set, instead of using selected lamps of the matrix as reference. In this way all displays made can be matched to a common reference. Color matching can be applied to the red lamps and to the blue lamps, using green in each case.

The color correction system just described can be used to match in color the pixels of a monochrome display. Thus, for example, the pixels of a yellow LED monochrome display may each be provided with a red LED surrounded by a number of the yellow LEDs, the red LED being used to standardise the hue of the pixel in the manner described above, making all the pixels the same apparent shade of yellow when viewed from a distance.

If the LED lamps are subject to color degradation, i.e. change of color with use, the lamps may cease to be adequately matched in color after a time. Color mismatch due to color degradation can be reduced by repriming from time to time.

LED matrixes are subject to dynamic variations in the light intensities of the lamps caused by transient thermal effects as messages displayed are changed. As the temperature rises, the light output drops by a factor J. J can be of the order of .01 per degree centigrade for some LEDs.

As a further embodiment of the invention, the display system is arranged to correct for the dynamic variation by altering the drive to each LED lamp by a temperature dependent dynamic intensity factor:

$$E = 1/(1 - J.\Delta t)$$

where Δt is the change in temperature, t, of the lamp. The temperature of the lamp is the temperature at its junction.

Using the basic arrangement of FIG.2, the value of E for each lamp is determined by measuring its current, I, both during priming time, when the lamps are all at the same temperature tp, and during display, when the lamps are at different temperatures. This is explained as follows. Assuming switches SR, SC to be ideal switches, for example mosfet transistors with negligible "on" resistance, and neglecting the effect of measuring resistance 30, the current I of a selected lamp is given by:

$$I = (V_D - V_L) / R_S$$

where V_L is the voltage across the lamp. The values of V_D and R_S are independent of temperature, and so, the change, ΔI, of lamp current due to change, Δt, of lamp temperature is given by:

$$\Delta I/\Delta t = -(\Delta V_L / \Delta t) / R_S$$

For an LED lamp $(\Delta V_L / \Delta t)$ is a constant, B (equal approximately to -.002 volts per degree centigrade), and so:

$$\Delta I / \Delta t = -B / R_S$$

from which:

$$\Delta t = -\Delta I.R_S / B$$

and substituting this in the expression for E, one gets:

$$E = 1 / (1+ \Delta I.R_S.J / B) \text{ ....(1)}$$

The procedure for evaluating and employing the correction factor E for each lamp, using the arrangement in FIG. 2, is as follows. As a prelude to priming, the display is blanked for a minute or more to allow all lamps L to reach the same steady temperature t_p. The G values are then established, for example using camera 21 as described before, taking care that the lamps are driven only briefly so as not to alter their temperatures. After the G values have been established, switch 20 is opened and switch 26 set to position 28 and each lamp L is turned on in turn, briefly so as not to alter its temperature, and its current, I_p, is measured and recorded in non-volatile memory. The temperature, t_p, at which the priming of the display has been carried out is read from sensor 41 and recorded in non-volatile memory. Switch 20 is preferably of the mosfet type.

During display, switch 26 is set to position 28 and the following procedure is carried out each time a row R is selected:

a) Switch 20 is opened and the current, I, of each lamp of the row is rapidly measured and temporarily recorded. This is done shifting a "one" along register 8. Because of the rapidity of measurement, the resultant light from the lamps is too weak to be seen.

b) For each lamp in the row, the value of E is calculated by microprocessor 3 from:

$$E = 1/\{1+ [I - I_p].R_s.J / B\} \qquad (2)$$

and temporarily stored. This expression is derived from equation (1).

c) Switch 20 is closed by microprocessor 3 and the row is driven for display with, for each lamp, the value A.E.G being used instead of G. By inclusion of the factor E, brilliance mismatch due to temperature differences between the lamps is now eliminated. The factor A is the same for all the lamps. A is chosen so that A.E cannot exceed unity. For example, it can be chosen to be 0.5.

By the above process, the light output is independent of both the ambient temperature and differences in temperature between lamps.

The value of J/B for a given LED can be determined at the end of priming by measuring the current I_p and the brightness W_p for the lamp at temperature t_p, then driving the lamp strongly for a few seconds to raise its (junction) temperature to some unknown value, t_u, and measuring the current I_u and the brightness W_u at this unknown temperature. The values are interrelated as follows:

$$1 - W_u / W_p = J. (t_u - t_p)$$

$$(I_u - I_p).R_s = B. (t_u - t_p)$$

from which:

$$J/B = (1 - W_u / W_p) / (I_u - I_p).R_s$$

The value for J/B is computed from this last expression. J/B can be determined and stored for each lamp individually.

As a modification of the above process, it is possible to allow the brightness of the display to diminish with ambient temperature rise while still eliminating lamp brightness variations that are due to lamp temperature differences. In this case the following value, E', is used in place of E in step (b) above:

$$E' = 1/\{1+[\,I - I_p + (t_a - t_p).B/R_s\,]\,R_s.J/B\} \ldots\ldots\ldots\ldots (3)$$

where t_a is the ambient temperature read from sensor 41 during display. The third term in the square bracket represents the effect on lamp current of changing the ambient temperature of the display from t_p to t_a.

LED matrixes are subject to dynamic variations in the colors of the lamps, caused by the dynamic junction temperature changes The effect is more noticeable with green and yellow lamps. These shift their color towards red as the temperature rises.

An embodiment of the invention providing intensity matching, dynamic intensity matching, color matching and dynamic color matching will now be discussed for an RGB display using the arrangement in FIG. 2 and having three LEDs per color pixel, one for each color. It is assumed that color matching is required only for the green lamps. In this case a color pixel is driven as follows:

$$N_r = E_r \,.\, A \,.\, [\,G_r \,.\, P_g\,] \,.\, [\,1 + Z_{rg} + Z_{rgd}\,]$$
$$N_g = E_g \,.\, A \,.\, [\,G_g \,.\, P_g\,]$$
$$N_b = E_b \,.\, A \,.\, [\,G_b \,.\, P_b\,]$$

where E_r, E_g, E_b are the E values for the red, green and blue lamp of the pixel, respectively. The new term, Z_{rgd}, is a dynamic color correction factor, given by:

$$Z_{rgd} = (\,t_a + t_{mr} - t\,) \,.\, Q$$

where t_{mr} is a design allowance, for example 50 degrees, for the maximum expected temperature rise of the junction temperature above ambient, t_a, and where t, as before, is the lamp temperature. Q is a constant defining the change in the proportion of red to green light generated by the green lamp that occurs when its temperature rises one degree. As its temperature, t, rises, the green lamp generates more red but, by Z_{rgd}, the red lamp gives less red, keeping the proportion of total red to green independent of temperature. Z_{rgd} can be re-expressed as:

$$Z_{rgd} = [\,(t_a - t_p + t_{mr}) - (t - t_p)\,] \,.\, Q$$

Since lamp temperature change Δt is related to lamp current change ΔI by:

$$\Delta t = \Delta I \,.\, R_s / B,$$

then $(t - t_p)$ can be replaced, to give:

$$Z_{rgd} = (t_a - t_p + t_{mr}).Q - (I - I_p).Q.R_s / B$$

from which:

$$Z_{rgd} = [(t_a - t_p + t_{mr}) .S.B / R_s] - (I - I_p).S \text{ .... } (4)$$

where:

$$S= Q.R_S / B$$

The value of S for a pixel can be determined at priming time by energising the green lamp to determine its current, I_p, its green light, W_{gp}, and its red light, W_{rgp}, when its junction temperature is t_p; and then its current, Iu, its green light, W_{gu}, and its red light, W_{rgu}, when the junction is at higher temperature t_u. The value of S is computed from:

$$S = [W_{rgu} / W_{gu} - W_{rgp} / W_{gp}] / (I_{gu} - I_{gp})$$

and stored in non-volatile memory. The expression in the square bracket is the change in the proportion of red to green light between the two sets of measurements.

The value of Z_{rgd} for a pixel is computed from equation (4). The factor in the square brackets in equation (4) is slow changing and can be evaluated once every minute. The other factor, $(I - I_p).S$, is computed every ten milliseconds or so, as is the value of Z_{rgd}.

As an alternative, dynamic color correction of the green can be provided by adding blue light to the pixel that increases with temperature, instead of adding red light that diminishes with temperature.

The RGB display can be reprimed, once a year for example, to reduce unevenness due to color degradation, as well as unevenness due to intensity degradation.

The dynamic compensation described so far is applicable to displays for which the voltage-current characteristics of the lamps do not change significantly due to degradation that occurs between one priming time and the next.

If the lamps used are of a type that exhibits marked change of voltage-current characteristics with degradation then, to minimise the effect of degradation on the accuracy of dynamic compensation without having to prime frequently, the system is arranged to repeatedly test itself once every day at 3 AM. At this time the display is blanked for a minute or more to allow the lamps all to cool to the same

temperature, t_m, given by temperature sensor 41. Temperature t_m is recorded and the lamp current, I_m, is measured and recorded for each lamp. During subsequent display I_m is used in place of I_p in equation (2), or its alternative, equation (3), in step (b) of dynamic intensity correction. I_m is also used in place of I_p in equation (4) for the dynamic color correction factor Z_{rgd}. As a bonus, the system can in this case detect degradation in a lamp without rerpriming. The system compares I_m with I_p and if it is found that

$$I_m < [\, I_p + (B/R).(t_m - t_p)\,]$$

then the internal resistance of the lamp has increased, indicating degradation. The brightness of the lamp can be turned up by the system by an amount dependent on the brightnesses of the lamps the are due to inequalities in their degradations.

It is possible to provide dynamic compensation by measuring the lamp voltages instead of their currents, since $\Delta V = -\Delta I.R_S$. In the arrangement in FIG. 4, by driving a lamp and closing switch SS of its column, the voltage of the lamp can be read, via amplifier 31 and analogue to digital converter 32. Switches SR and SS are in this case preferably of the mosfet type, having minimal voltage drop.

For each of the arrangements of FIG. 2 and FIG. 4 it is possible to replace camera sensor 21 with a single photosensor, such as a phototransistor, the output of which is fed to a tuned circuit, such as a one megacycle crystal , which feeds a demodulator. In this case, for measurements during priming, lamps L are energised only one at a time each with a pulse train of one million pulses per second.

Lamps L may be mounted on tiles that are butted together, with each tile having, for example, a 16x16 matrix of lamps. Tile 60 illustrated in FIG. 5 includes lamps L soldered to the back of a printed circuit board 61 and a translucent light-guide sheet 62 mounted at the front of the board. Sheet 62 has a light disperser 63 opposite each lamp L and a light disperser 65 opposite a phototransistor 64 mounted at the center of the tile to receive light from sheet 62. Dispersers 63, 65 may comprise facets, grooves or roughened surfaces in sheet 62. The output of photosensor 64 is fed via suitable electronics to a filter that passes only one megacycle. At 3 AM each day the system is arranged to energise each lamp in turn at one million pulses per second and to measure the output of the filter circuit during such energisation and to record the measurement and ascertain if there has been any change in the light output of the lamp due to degradation, relative to an

earlier measurement made by the same procedure, and to correct for the detected change of light. Sensor 64 may be replaced with a fiber optic guide that transmits light from the tile to a sensor that is common to all of the tiles. Alternatively, each tile may be provided with two fiber optic guides each used to sense lamps on the tile that are not close to it. By this means, together with appropriate individual tailoring of each lamp disperser 63, it is possible to achieve sensing of the lamps that is fairly independent of lamp position on the tile, enabling the sensing system to be used for initial priming without having to use different multiplication factors to compensate for differences in light transmission between the lamps and disperser 65. The common sensor for all the fiber light guides can be a unit arranged to measure red, green and blue components of light separately. Because the sensor is frequency selective at one megacycle, it can detect the one megacycle test light even if this light is very weak, and it ignores ambient light. If it is desired to use LEDs with axial leads, mounted on the front of printed circuit board 61, the light guide sheet can be rearranged. It can, for example, have holes through which the LEDs protrude, with dispersers in the side walls of the holes for collecting side light from the LEDs. The holes can flare out so that their diameters are larger at the outer surface of the hole than at the inner surface.

Shift registers 1 and 7 can be replaced with gates arranged for rapid loading of drive registers 2 and 8 with bytes or words directly from microprocessor 3 or any external memory connected to it.

Information, such as Pr, Pg, Pb, specifying what a pixel is required to display is classified here as command information. By contrast, information or parameters relating to properties of the lamps, such as temperature, current, G value, B value, Zrg value, E value, etc., of the lamp is classified here as physical information.

As mentioned before in connection with priming, the G values can be computed by a laptop computer. The same is true of the non-dynamic color correction factors, such as Z_{rg}. The laptop computer can serve as the user's controller for entering messages and images into the display system. In this case, and if dynamic compensation is not required, the laptop computer can be used instead of microprocessor 3 for storing the G and Z values and for computing and transmitting to the LED display drive values for the lamps, such as the N values.

FIG. 6 illustrates an arrangement for automatic priming by the display system, using a color camera 21 as in FIG. 2 or FIG. 4. Attached to cabinet 101 is a motor unit 102 containing a geared motor the output shaft of which is connected to an arm 103 which extends horizontally and is connected at its far end to a vertically and downwardly extending arm 104. Connected with the bottom end of arm 104 is camera 21. Arm 103 is movable between the position shown, for which camera 21 is pointed at the center of matrix 110, so as to take pictures of the whole of the matrix, and a parked position where camera 21 is nested in a pocket 105 in cabinet 101, with arm 103 parallel to the top of cabinet 101 and above the matrix and with vertical arm to the right of the matrix. When in the parked position, arms 103,104 and camera 21 do not interfere with normal viewing of the display. The output of camera 21 is relayed to microprocessor 3 by means of flexible cable running along arms 6 and 5 and on into the cabinet The flexible cable includes wires for control of motor unit 102 and camera 21 by microprocessor 3. Attached to cabinet 3 is a weather detector 106, electrically connected to microprocessor 3.

Microprocessor 3 is arranged to prime the display once every twenty days or so, at 3 AM, so as to correct for any inequalities in the appearances of the lamps caused, for example, by LED degradation. It causes camera 21 to be swung out of its parking place to the position shown and lights the lamps and takes the pictures automatically to ascertain the G and Z values. After the priming, it returns camera 21 to its parking position. Prior to going through the procedure described, microprocessor 3 first examines the output of weather sensor 106. If the sensor indicates bad weather, i.e. wet or stormy weather, microprocessor 3 postpones the priming for 24 hours. If lamps L include lenses, then the measurements taken with camera 21, which is now much closer to the matrix than in the case of FIG.1, will need to be corrected in accordance with lamp position to take into account the fact that pixels not on the optical axis of the camera appear to the camera less bright than the central pixels, because of the lamp lenses. In this case appropriate angle-dependent correction factors are stored in non-volatile memory and used by microprocessor 3 to get correct brightness readings.

FIGS. 7, 8 illustrate another device according to the invention for sensing the lamps, which avoids the need for a camera for automatic repriming. Equalization of

the lamps is by the lamp drive arrangements previously described with reference to FIG. 2,4. Cabinet 101 of the display includes a sheet 111 which extends the width and height of the cabinet. Mounted on the front of sheet 111 is a matrix 110 comprising LED tiles 112 . Each tile 112 includes a matrix of pixels 113. Each pixel includes a red lamp, a green lamp and a blue lamp. Each of the three lamps of the pixel may may comprise one or more LEDs. Mounted onto sheet 111 above matrix 110 is a horizontal track 124 to which is attached a gear strip 125. Track 124 carries a motorised carriage 126 which is driven by a stepping motor 127. A worm gear 128 on the output shaft of motor 127 is engaged with a gear wheel 129, and gear wheel 129 is engaged with gear strip 125. Thus by driving motor 127 carriage 126 is urged to travel along track 124. Carriage 126 includes a pair of wheels 130 engaging with the top of track 124 and a similar pair of wheels 131 engaging with the bottom of track 124. A track 124 is also provided below matrix 1 and carries a carriage similar to the top one. Between top and bottom carriages 126 is mounted an elongate scanning member 114 extending vertically. Top and bottom stepping motors 127 are wired in parallel so as to be always driven in unison, maintaining the verticality of scanning member 114. Scanning member 114 is tensioned by means of a leaf spring 115 which is coupled to the bottom of member 114 by a hinge 116 having a rotatable leaf 117. By this tensioning arrangement scanning member 114 can be thin and light and pulled straight, even if the matrix is as much as 10 meters high.

Attached to top carriage 126 is a ribbon cable 118 which carries signals for stepping motors 127. originating from microprocessor 3, and other signals. Ribbon cable 118 passes round a pulley 132, attached to sheet 111 and is tensioned by a pulley 133, which is pulled down by a weight 134. Cable 118 terminates in a junction box 135, which is connected to microprocessor 3 for motor control and light sensing operations. Pulley 133 and its weight 134 are confined from swinging left and right by a guide channel not shown. Running along the length of scanning member 114, not shown, is a cable for driving lower motor 127. Tracks 124 and ribbon cable 118 are hidden from view by border 138. When not in use, scanning member 114 is parked behind the left hand portion of border 138, hidden from view and not interfering with the appearance of the display. Ribbon cable 118 may be replaced with a wireless data link if top carriage 126 is provided with electrical power means, such as a rechargeable battery which is given a charge when

carriage 126 is parked. Box 137 can house the battery and power transistors for controlling motors 127. For each row of pixels 113 there is provided on scanning member 114 a sensor 136 arranged to receive light from the pixels of the row. Sensors 136 are matched and are selected under control of microprocessor 3. The light falling on sensors 136 is measured, digitized, and stored. The stored digital values are analysed by microprocessor 3 to determine the G and Z values.

Microprocessor 3 is arranged to prime the display once every twenty days or so, at 3 AM. To measure the relative intensities of the lamps , microprocessor 3 turns off all lamps of the matrix, pauses for a few minutes to allow the lamps all to cool to the same temperature, and then moves scanning member 114 out of its parking position to the position where its column of light receiving sensors 136 is opposite the first column of pixels 113 of the matrix. It then turns on each lamp of the column in turn with maximum drive, leaving the other lamps of the column off, and measures the light output of the lamp and records a digitized value indicative of the measurement in memory. After measuring all the lamps of the column, the system advances scanning member 114 to the next column. After measuring all the lamps of the last column, the system returns scanning member 114 to the parking position. At this point readings for all the lamps are held in memory. Light sensor 136 may contain three photosensing elements: one responsive to red, one to green, and one to blue, so as to be able to detect and correct for color mismatch of the lamps as well as intensity mismatch. As an alternative to turning on and measuring only one lamp in a column at a time, it is possible, instead, to turn on and measure several at a time, providing each turned on lamp is separated from the next turned on lamp by at least three dark pixels, to ensure that each sensor 136 measures LED light only from the lighted pixel of its row.

It is possible to have only a single RGB sensor, mounted in box 137, for example. In this case each sensor 136 is replaced with a light guide the input of which receives light from the row of pixels and the output of which is directed to the common RGB sensor. Only one lamp is turned on at a time. The light sensor can be made responsive only to light chopped at a certain frequency, and the lamp light interrupted at this frequency, so as to prevent fluctuating ambient light from corrupting the measurements.

I claim:

1. A display system having a display face comprising an array of areas each of which is controlled to appear either luminous or not, each said area comprising lamp means individual to the area which when turned on causes luminous appearance of the area, said display system including lamp drive means, register means controlling said lamp drive means, a bit of said register means controlling selection of at least one of said lamp means, and control means arranged for repeatedly loading said register means, the brilliance of said one of said lamp means being individually adjustable by altering the proportion of time for which said bit is set to select said one of said lamp means, said display system including storage means storing physical information particular to said one of said lamp means derived by measurement of at least one of the current and light intensity of said one of said lamp means, said display system being arranged for setting said proportion of time to be dependent on said physical information and for reducing differences in the appearances of said areas that are due to differences in the properties of their respective lamp means.

2. A display system according to claim 1 wherein said differences in appearances comprise differences in color.

3. A display system according to claim 1 wherein at least part of said physical information is derived using a camera pointed at said array.

4. A display according to claim 1 arranged to match the brightnesses of several contiguous said areas arranged in a row.

5. A display system according to claim 1 arranged by measurement of one of the currents of the lamp means and the voltages of the lamp means to reduce differences in the appearances of said areas that are due to differences in the temperatures of their lamp means.

6. A display system according to claim 1 arranged to measure the current of said one of said lamp means including a resistor through which the current of the lamp

means is passed, said resistor being shunted with a switch.

7. A display system according to claim 1 wherein said bit of said register serves to select a plurality of said lamp means and to provide variable drive for matching their brightnesses.

8. A display system according to claim 1 wherein at least part of said physical information is derived using light-sensitive means arranged for measuring light from said lamp means.

9. A display system according to claim 1 arranged to automatically measure from time to time at least one of the currents, the voltages, and the light intensities of said lamp means.

10. A display system according to claim 1 wherein said physical information is derived by measurement employing said register means.

11. A display system according to claim 1 including, at least temporarily, light-sensitive means means exposed for said measurement to a plurality of said areas simultaneously.

12. A display system according to claim 1 including an array of lamp means of the same nominal color every one of which has physical information individual to it stored in said storage means.

13. A display system according to claim 1 including, at least temporarily, a computer having a display screen and holding a record of said physical information.

14. A display system according to claim 1 arranged to apply to a lamp means of a said area a pulse having a width proportional to physical information stored for that lamp means.

15. A display system according to claim 1 arranged to ascertain the voltage across each of a plurality of said lamp means individually.

16. A display system according to claim 1 including constant current drive for the

lamp means.

17. A display system according to claim 1 arranged to apply constant current to the lamp means the magnitude of which diminishes with increase of the ambient temperature of the lamp means at least when the ambient temperature exceeds a predetermined value.

18. A display system having a display face comprising an array of areas each of which is controlled to appear either luminous or not, each said area comprising lamp means individual to the area which, when turned on, causes luminous appearance of the area, said display system including means for driving said lamp means, the brilliance of each of said lamp means being individually adjustable, said display system also including means storing for each of said lamp means a parameter particular to the lamp means and including, at least temporarily, light-sensing means exposed to all of said areas simultaneously the output of which determines the values of said parameters, said display system being arranged to reduce differences in the brightnesses of said areas that are due to differences in the properties of their respective lamp means.

19. A display system according to claim 18 including sensing means arranged to sense the ambient light falling on said areas the output of which controls the extent of said reduction of differences in appearances.

20. A display system according to claim 18 including means defining a reference light intensity and wherein the light intensities of said areas are set to be matched to said reference light intensity.

21. A display system having a front face comprising an array of areas each of which is controlled to appear either luminous or not, each said area comprising lamp means individual to the area which when turned on causes luminous appearance of the area, said display system including lamp drive means by which the brilliance of each of said lamp means is individually adjustable and including means storing physical information particular to each of said lamp means derived by measurement of at least one of the current and light intensity of the lamp means, said display system being arranged for setting the brilliance of each said lamp

means to be dependent on said physical information for the lamp means, and for reducing dissimilarities in the appearances of said areas that are due to differences in the initial efficiencies of the lamp means and at least one of:

differences in the initial colors of the lamp means,
differences in intensity degradations of the lamp means,
differences in color degradations of the lamp means and
differences in the temperatures of the lamp means.

22. In a display system having a front face comprising an array of areas each of which is arranged to appear either luminous or not, each said area comprising lamp means individual to the area which when turned on causes luminous appearance of the area, a method of controlling the appearances of said areas comprising the steps of:

providing a display face with an array of areas each comprising lamp means,
providing variable lamp drive means for control of the light intensities of said lamp means,
providing storage means for storing data,
pointing a camera at said array,
capturing at least one image of the array with a number of said lamp means on,
analyzing said at least one image to obtain readings of said areas with regard to at least one of brightness and color,
storing physical information for each said lamp means derived from said analysis,
and turning on said lamp means for display each in accordance with its said stored information to reduce differences in the appearances of said areas that are due to differences in the properties of their associated lamp means.

23. The method of claim 22 including the steps of obtaining a reading for the light emanating from a said area with the lamp means of the area off, and subtracting this reading from one taken for the same area with a lamp means of the area on.

24. The method of claim 22 employing a computer having a display screen and arranged to hold at least temporarily a record of physical information derived from said analysis.

25. A display system having a display face comprising an array of areas each of

which is controlled to appear either luminous or not, each said area comprising lamp means individual to the area which when turned on causes luminous appearance of the area, said display system including lamp drive means by which the brilliance of each of said lamp means is individually adjustable, said display system being arranged to automatically ascertain changes in properties of the lamp means occurring between two occasions by measurements taken on said occasions of at least one of the currents, the voltages, and the light intensities of said lamp means, and to reduce dissimilarities in the appearances of said areas that are due to said changes.

26. A display system having a front face comprising an array of areas each of which is controlled to appear either luminous or not, each said area comprising first and second lamp means individual to the area, said first and second lamp means being of first and second designated color, respectively; said display system including means driving said first and second lamp means by which the brilliance of at least each of said second lamp means is individually adjustable; said display system including means defining a reference color and means storing for each of said first lamp means physical information indicative of its color deviation from said reference color, said display system being arranged, when for a given said area light of said first designated color is required, to supplement light from the first lamp means of the area with an amount of light from the second lamp means of the area, said amount being dependent on said physical information stored for the first lamp means of the area, said display system being arranged to reduce differences in the apparent colors of said areas that are due to differences in the colors of their first lamp means.

27. A display system having a front face comprising an array of areas each of which is controlled to appear either luminous or not, each said area comprising lamp means individual to the area, said display system including lamp drive means, the brilliance of each of said lamp means being individually adjustable, said display system including means detecting for each of said lamp means change in one of the voltage and the current of the lamp means caused by temperature change of the lamp means, said display system being arranged to reduce differences in the appearances of said areas that are due to differences in the temperatures of their respective lamp means.

28. A display system having a front face comprising an array of areas each of which is controlled to appear either luminous or not, each said area comprising lamp means individual to the area which, when turned on, causes luminous appearance of the area, the brilliance of each of said lamp means being individually adjustable, said display system including means driving a said lamp means repetitively at a defined rate, said display system including means storing for each of said lamp means a parameter particular to the lamp means and including light-sensing means arranged for receiving and measuring light from the lamp means of said areas the output of which determines the values of said parameters, said light sensing means including filter means selective to signals changing at said defined repetition rate, said display system being arranged to reduce differences in the brightnesses of said areas that are due to differences in the properties of their respective lamp means.

29. A display system according to claim 28 including light guide means arranged for guiding light from each lamp means of said array to a common light sensor.

30. A display system according to claim 28 including a sheet of translucent material arranged for guiding light from each lamp means of said array to a common light sensor.

31. A display system having a display face comprising a matrix of areas each of which is controlled to appear either luminous or not, each said area comprising lamp means individual to the area which, when turned on, causes luminous appearance of the area, said display system including means for driving said lamp means, the brilliance of each of said lamp means being individually adjustable, said display system also including means storing for each of said lamp means at least one parameter particular to the lamp means and including a light sensing assembly, the output of which determines the values of said parameters, movable by said display system between a first position where it is parked so as not to interfere with viewing of said matrix, and a second position for which said light sensing assembly is opposite a portion of said matrix, said display system being arranged to reduce differences in the appearances of said areas that are due to differences in the properties of their respective lamp means.

32. A display system according to claim 31 wherein said light sensing assembly is rotatable.

33. A display system according to claim 31 wherein said light sensing assembly is rotatable and carries a camera.

34. A display system according to claim 31 wherein said light sensing assembly is arranged for travelling in a direction parallel to the plane of said matrix.

35. A display system according to claim 31 wherein a said lamp means is arranged to produce light pulsating at a predefined frequency and there is provided a light sensing system responsive only to said pulsating light.

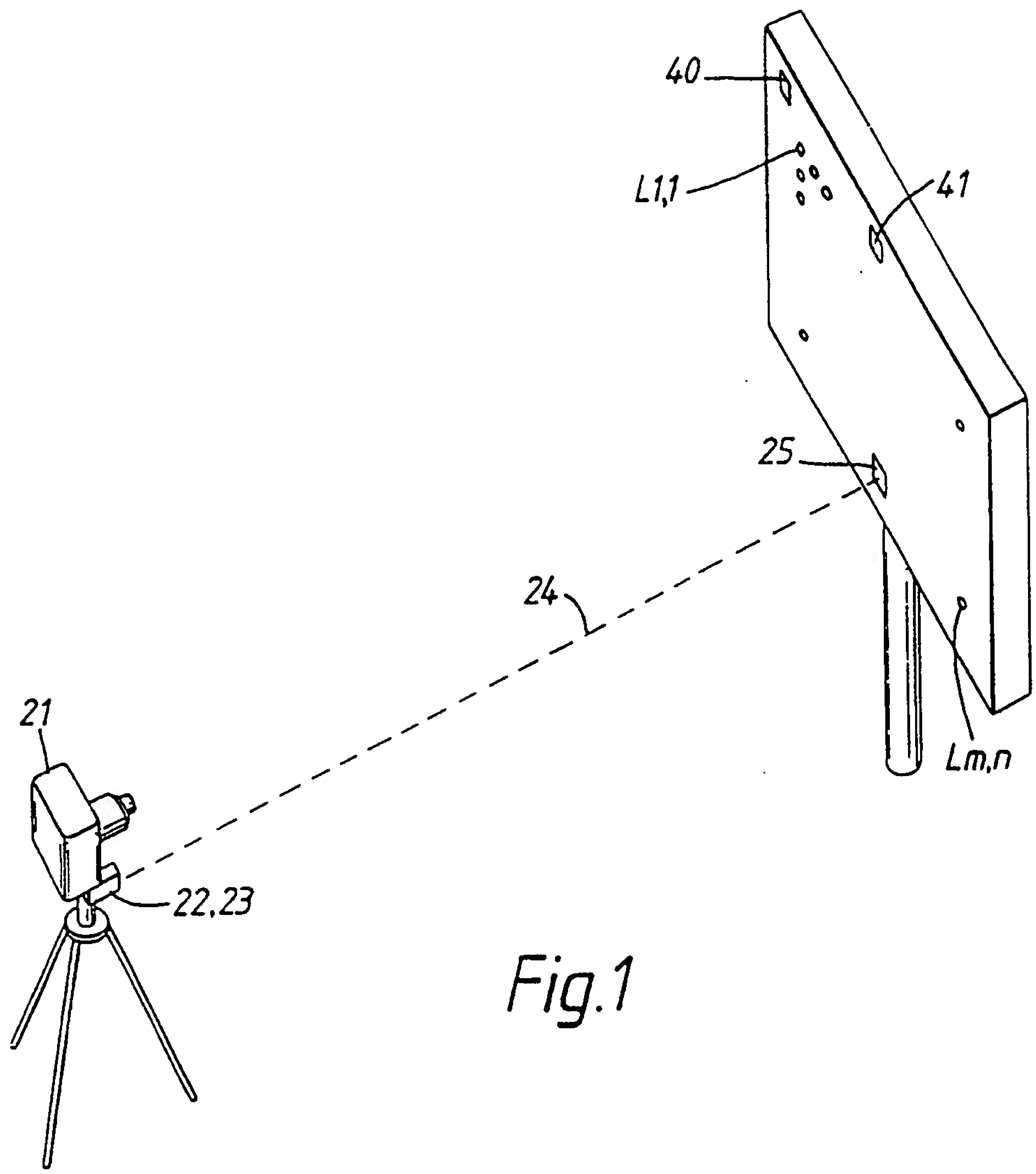


Fig.1

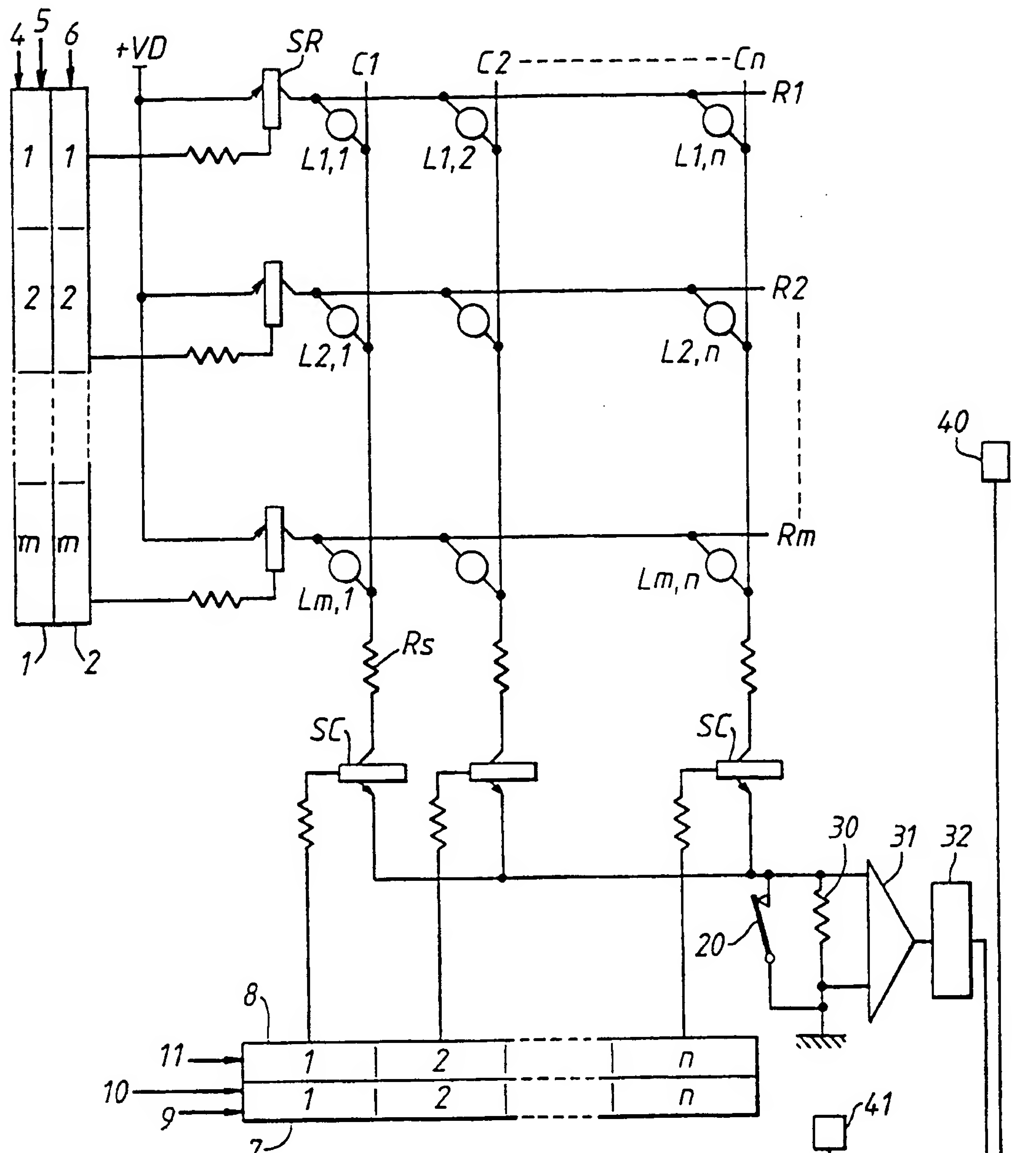
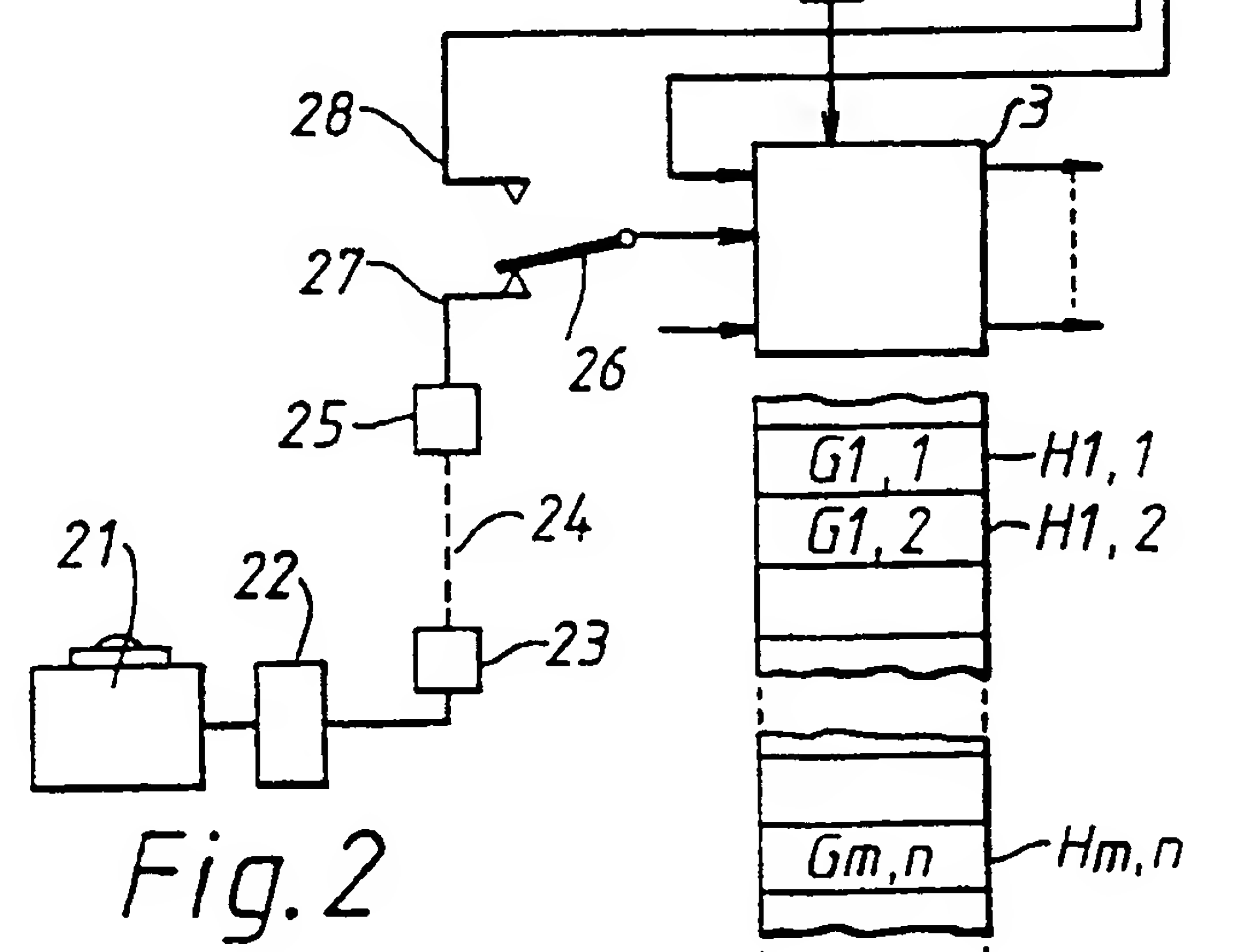



Fig.2

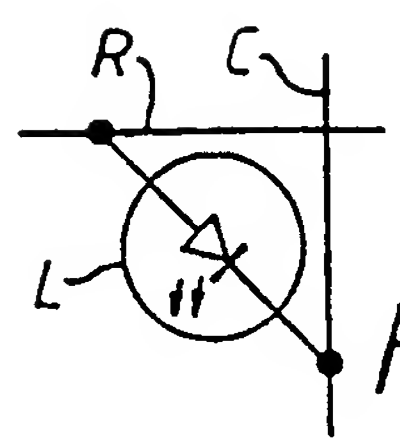


Fig.3a

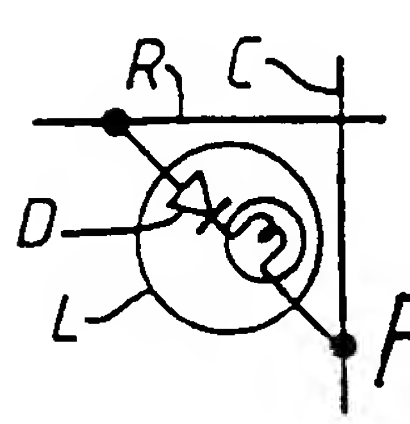


Fig.3b

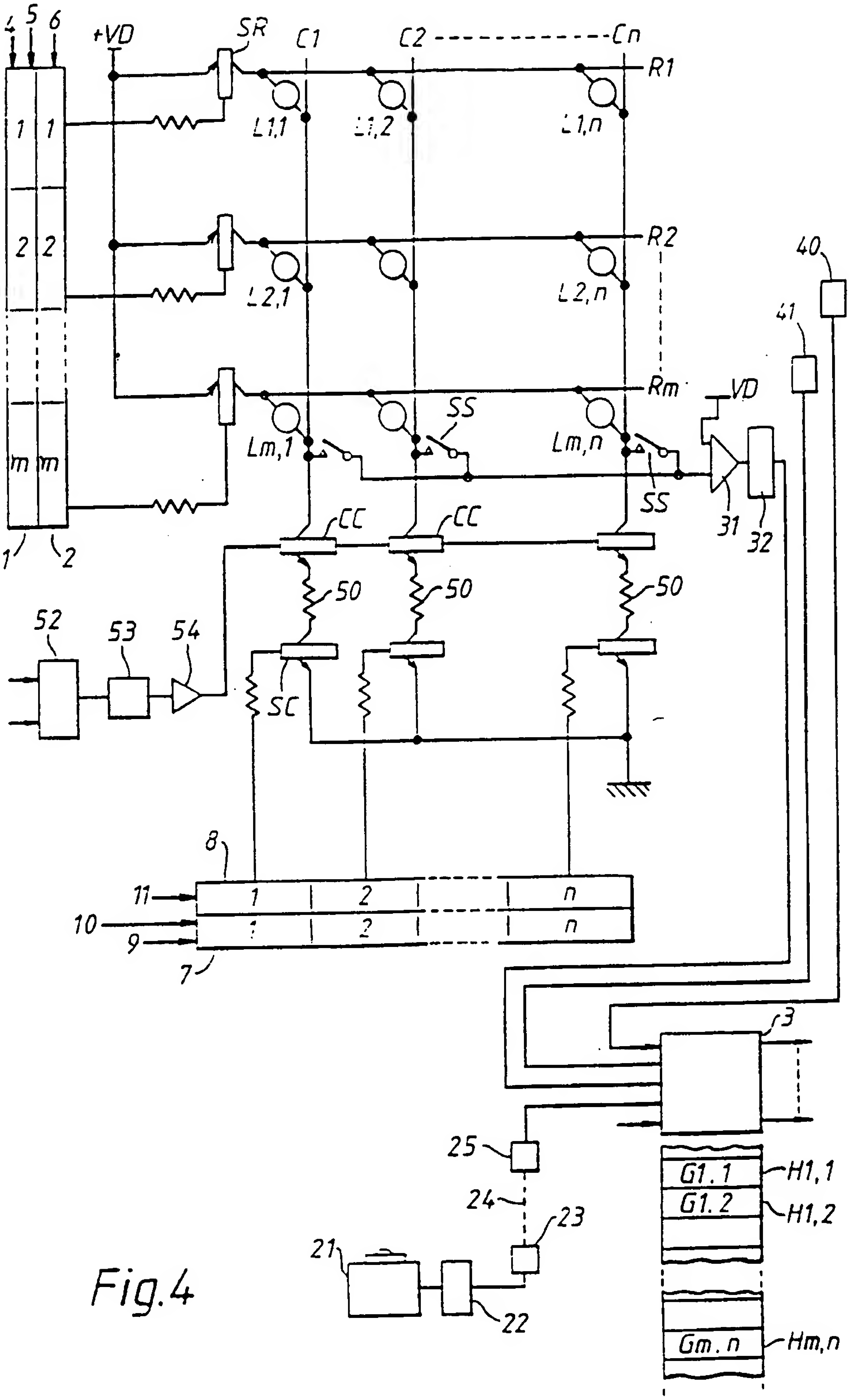

4
5
6
+VD
SR
C1
C2
Cn
R1
R2
Rm
L1,1
L1,2
L1,n
L2,1
L2,n
Lm,1
Lm,n
SS
VD
31
32
40
41
CC
50
52
53
54
SC
8
11
10
9
7
1
2
n
m
3
25
24
23
21
22
G1.1
G1.2
Gm.n
H1,1
H1,2
Hm,n

Fig.4

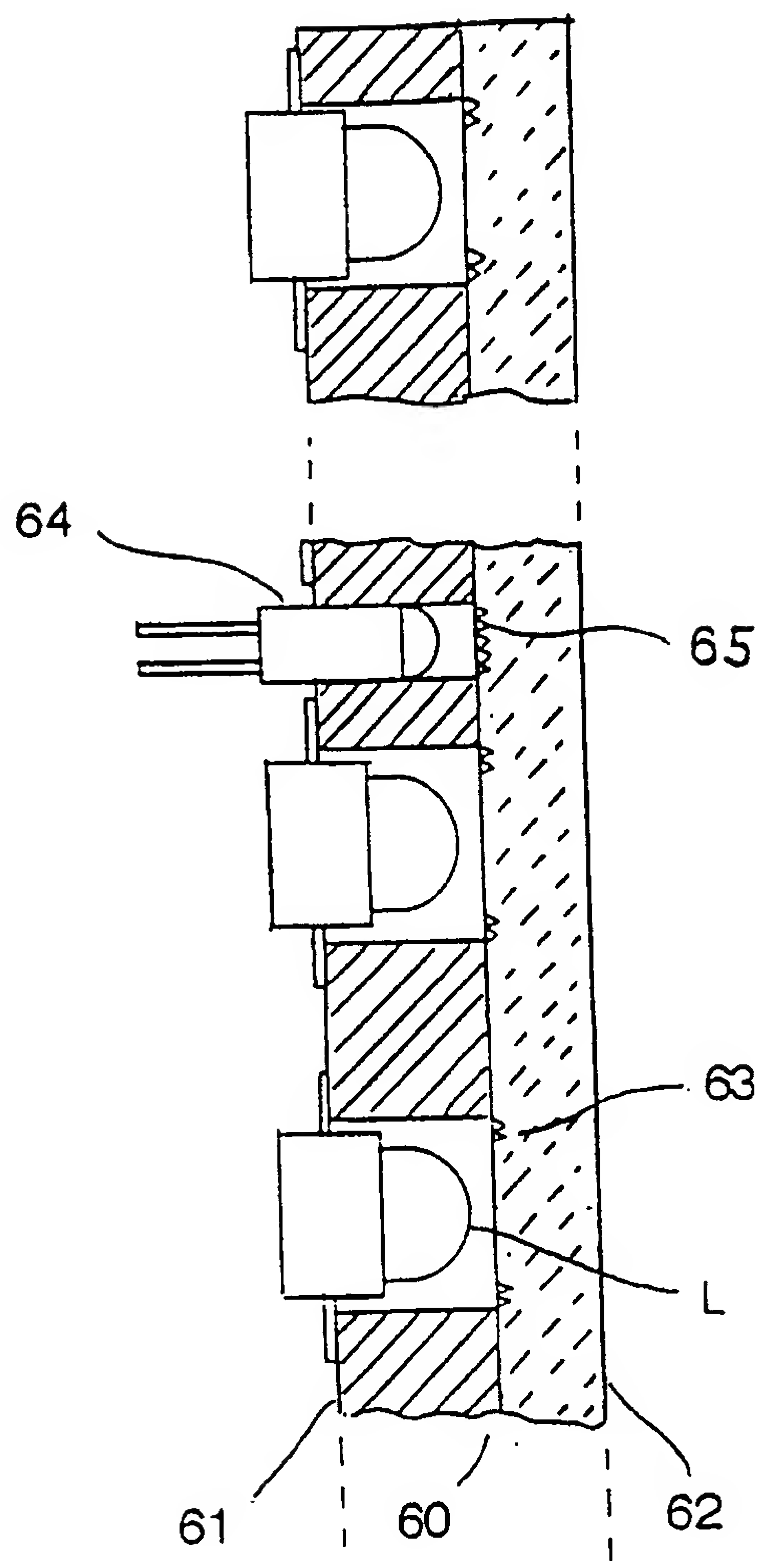


Fig. 5

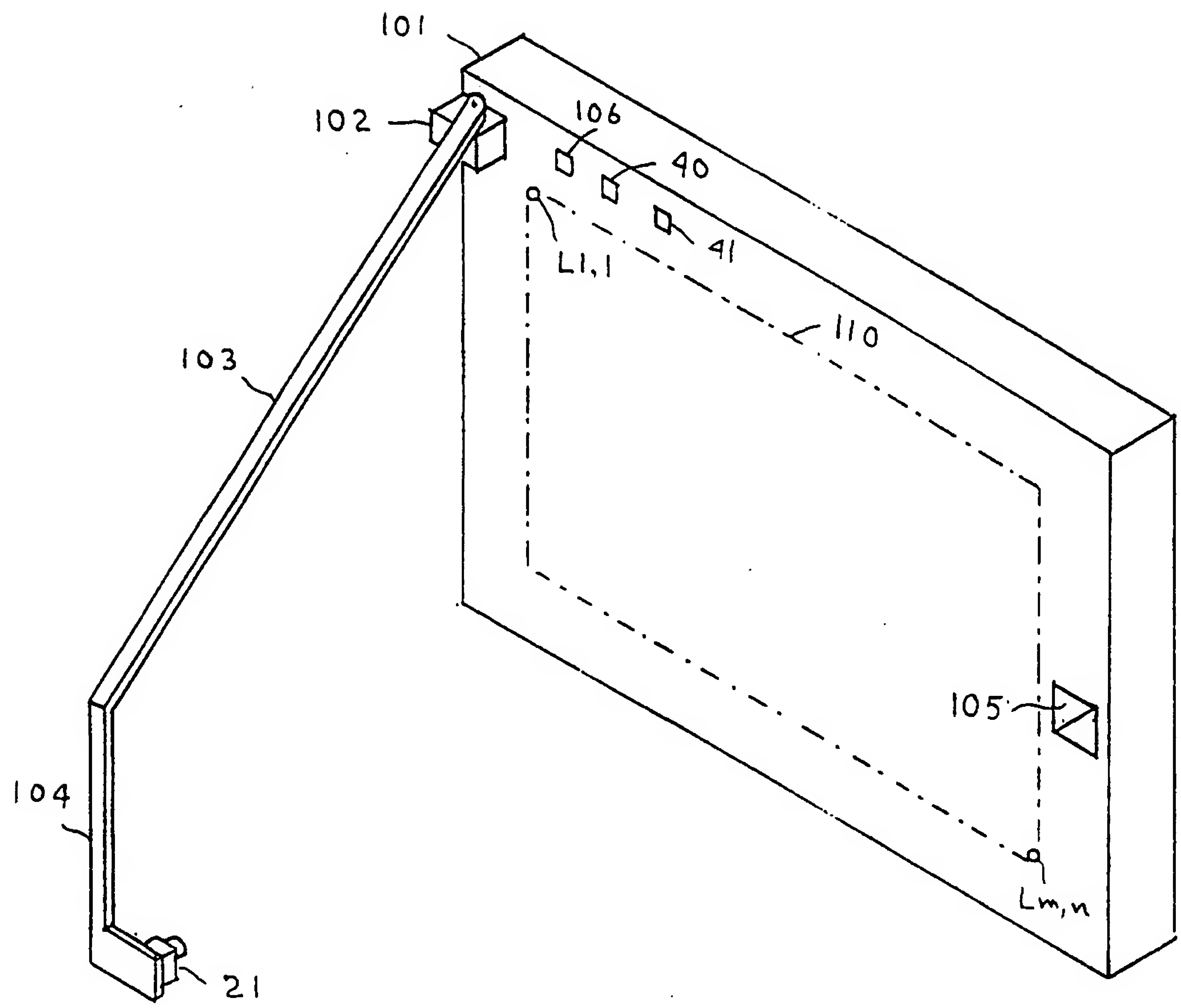
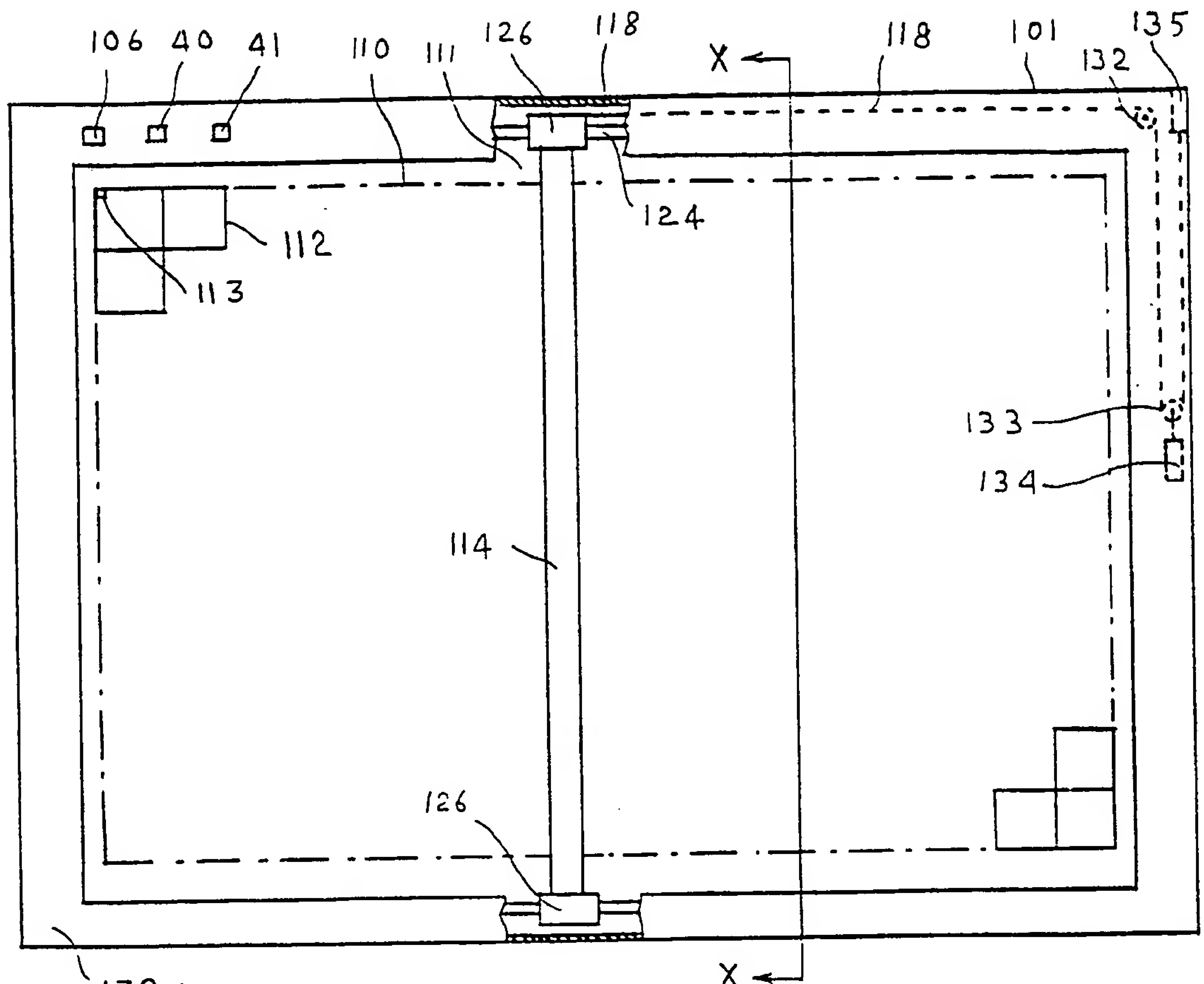


FIG. 6


106
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X
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113
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133
134
114
126
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X

FIG. 7

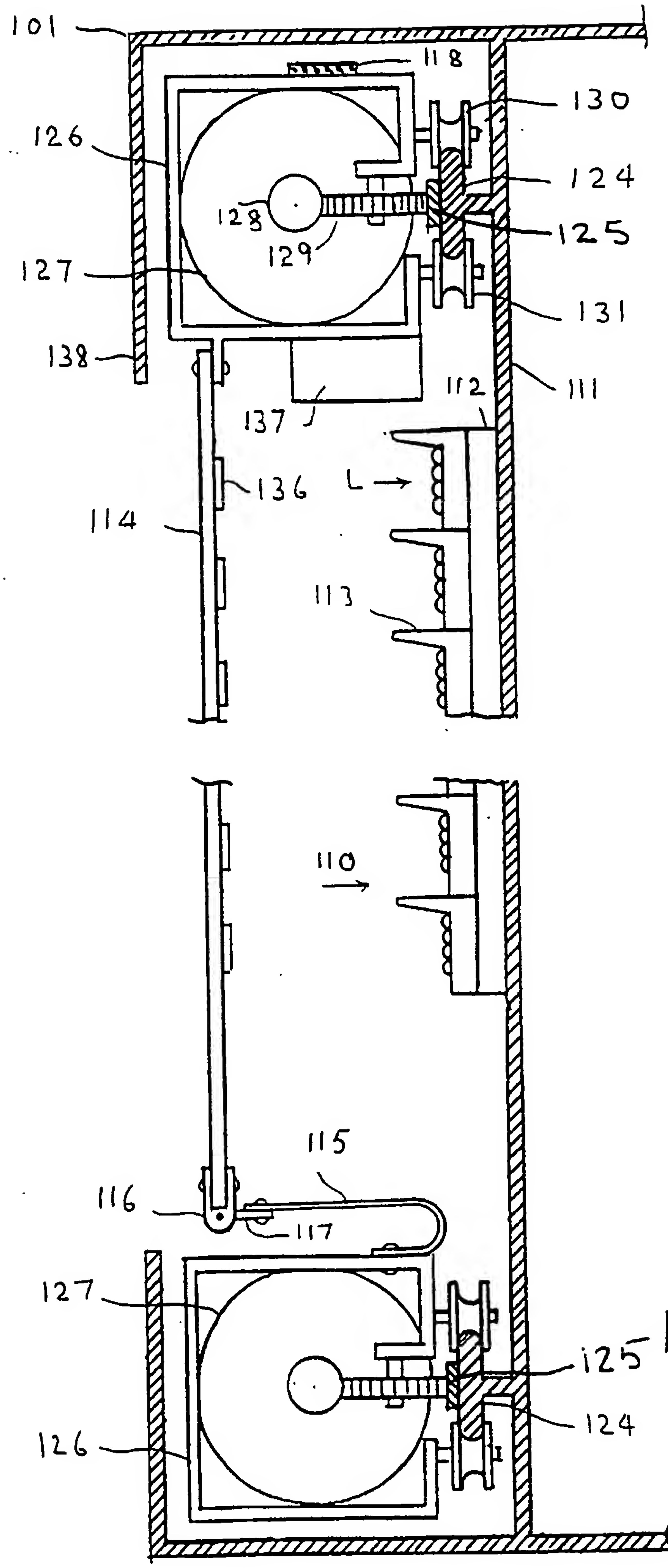
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FIG. 8

INTERNATIONAL SEARCH REPORT

Inter ional Application No
PCT/GB 97/01315

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G09G3/32 G09G3/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G09G G09F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 702 347 A (KABUSHIKI KAISHA TOSHIBA) 20 March 1996 see abstract; figures 2-9	1,7,14, 18
A		5,7,10, 15, 19-22, 26-28,31
	see column 3, line 42 - column 6, line 29 see column 7, line 15 - column 8, line 31 see column 9, line 43 - column 9, line 45 ---	
A	US 5 594 463 A (SAKAMOTO) 14 January 1997 see abstract see column 1, line 56 - column 3, line 14 ---	9,14,16, 25,27
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
29 January 1998	05/02/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van Roost, L

Form PCT/ISA/210 (second sheet) (July 1992)

Inter ·nal Application No
PCT/GB 97/01315

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 825 201 A (WATANABE ET AL.) 25 April 1989 see abstract; figures 1,5 see column 3, line 3 - column 3, line 62 see column 5, line 35 - column 6, line 26 ---	1-5,8,9, 11,18, 21,22, 24,28, 31,33
A	PATENT ABSTRACTS OF JAPAN vol. 95, no. 11, 26 December 1995 & JP 07 199861 A (TAKIRON CO LTD), 4 August 1995, see abstract -----	1,24

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INTERNATIONAL SEARCH REPORT

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Inter   onal Application No
PCT/GB 97/01315

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US 5594463 A	14-01-97	JP 7036409 A	07-02-95
		JP 7036410 A	07-02-95
US 4825201 A	25-04-89	NONE	